FLOATING MODULAR BREAKWATER

FIELD OF THE INVENTION

The present invention generally relates to breakwaters, piers, docks, wave breakers, wharfs, etc., hereinafter in the specification and claims referred to collectively as *breakwaters*, used for protecting coasts namely shore lines and harbors, and offshore elements e.g. marine watercrafts and structures. More specifically the invention is concerned with floating such elements, useful in a variety of embodiments and different purposes.

BACKGROUND OF THE INVENTION

Maritime structures of the concerned type have many purposes. For example, they may be used to minimize wave damage and for erosion control of shores and structures (either at shoreline or at open waters). Furthermore, such structures may be used to form wharfs for ships to moor and for connecting with land. Other examples of use of such structures may be bounding of non-shore areas to define restricted areas, e.g. a swimming zone, maritime sports zone etc. Alternatively, such bounding may be used for bordering hazardous areas or areas of ecological danger (for example oil leaks, etc).

A wide variety of such breakwater structures have been proposed throughout the years of mankind exploring open waters. One type of such breakwater requires employment of massive seabed foundations which are time consuming in setting up, as well as expensive and requiring special equipment for deployment thereof. Floating, flexible such structures, collectively belong to another type, where substantially little time is required for setting up a breakwater or the like, whilst

being relatively cheap and offering modularity and flexibility as far shape and features, e.g. aesthetics, water circulation, knock-down time, etc.

However, floating breakwater structures have some disadvantages setting as examples ineffectiveness in reducing height of slow waves, susceptibility to structural failure at extreme conditions, maintenance requirements, etc. One other significant draw back of some prior art floating breakwater structures is the problem of slack/taut of cables of such structures, e.g. owing to waves, tide, etc.

Several prior art publications disclose floating breakwaters, amongst which are the following US Patents: 2,185,458, 3,792,589, 3,863,455, 3,969,901, 4,316,994, 4,693,631, 4,715,744, 5,429,452, 5,310,283, 5,702,203 and 6,408,780.

Another type of breakwaters is the so-called offshore floating breakwater, used for attenuating waves and reduce sea state wave conditions for safe marine vessel operation. A detailed study concerned with such breakwaters was disclosed in the article 'Field and numerical comparisons of the RIBS floating breakwater', by M. Briggs, W. Ye, Z. Demirbilek and J. Zhang. published in the Journal of Hydraulic Research, Vol. 40, 2002, No. 3.

It is an object of the present invention to provide a novel modular floating breakwater structure of the concerned type, requiring substantially little storage space, cheap in transportation costs and fitted for easy and rapid deployment into its operative state and has some substantive advantages regarding durability and management of dynamic forces developing under wave force.

SUMMARY OF THE INVENTION

The present invention calls for a modular breakwater suitable for attenuating waves in open waters and water ways. The breakwater comprises a plurality of rods assembled in a fixed parallel array for positioning in the water at a substantially vertical position at least partially submersed in water, whereby the assembly is flexible and is deformed into an arched/bowed structure.

According to the present invention there is provided a floating breakwater assembly comprising an array of elongate rods articulated to one another for

extending at a substantial vertical position at least partially submersed in water, wherein said rods are made of a flexible material and where the array is elastically deformable into an arcuate shape by bending the array.

The breakwater assembly is flexibly deformable in different ways depending on its intended use. For example, the breakwater may be part of a port gateway, where the width of the opening is controllable. It may also be part of an off-shore moor, fixed at the open waters (e.g. suitable as a moor or for protection of constructions like a lighthouse etc.) or deployable from a ship for temporary and rapid assembly, e.g. while unloading cargo from a ship to barges, etc. Other examples are establishing a protected zone of attenuated waves suitable as a sport resort and the like, etc. In each case the span of the assembly, the size of the arch and its direction are determined according to the intended use.

The breakwater may be elastically deformed by pulling the ends thereof in a direction so as to form a bow. This may be carried out for example by pulling the ends directly towards one another, or puling them at a direction giving rise to a vector of force in that direction. Elastic deformation may be obtained by applying force at one or both ends of the array.

The breakwater is made of a plurality of rods, each of which may be constructed of several rod segments, said segments being substantially straight tubular elements made of flexible material allowing its elastic bending. The rod segments may be made of any suitable material, each imparting it with different mechanical properties like elasticity, strength, etc. and is typically manufactured by extrusion. For example, the rod segments may be manufactured of any of the following materials and their combinations: plastic, epoxy, polyester, etc., and may be reinforced by various fibers such as glass, charcoal, Kevlar®, etc.

In order to retain the array floating at a substantially vertical position, one or more upper rods of the array have buoyant properties, e.g. hollow rods filled with foamed polyurethane, etc., whilst rods below said buoying rods are hollow and are filled with water, to thereby stabilize the assembly and support it vertically.

The rods of the assembly are retained at an array such that they extend parallel to one another and about a substantially vertical plane. This is obtained by a rigid connecting element receiving the rods and supporting them at a fixed position. The connecting element is also suitable for applying force on portions of the array to obtain its desired elastic deformation.

According to one particular embodiment, ends of the array are anchored e.g. to an anchor laying or fixed to the sea bed, thus giving rise to generation some vector of force also at a vertical direction. According to a different embodiment of the invention, the array is attached to a buoy which in turn is anchored, thereby substantially reducing the vertical vector of force.

The breakwater is stabilized at an substantially upright floating position by a load of weight associated with a lower end thereof, e.g. suspended from the lower rod or integral therewith or insertable therein.

The breakwater according to some of its applications is fitted with mooring arrangements, such as suitable boat/ship anchoring facilities. According to a specfic arrangement, there is provided one or more mooring rods pivotally secured to the array and tiltable between a stow position and an operative position, wherein at said operative position either a stern or bow of a mooring boat is secured to a free end of a mooring rod and an other of the stern or bow of the mooring boat is secured to the array.

According to still an application of the present invention, a deck is mounted on the breakwater, for easy access along the breakwater and optionally for transfer facilities such as electricity, fresh water supply, sewage suction, communication cables, etc. The deck may be integrally formed with an upper rod of the array, or may be mounted thereon. The deck may be constructed of a plurality of segments attached to or mounted on the rods and may also have buoyant parameters to assist in establishing buoyancy and positioning of the array in the water.

Furthermore, it is possible for one or more rod segments of the array have different elasticity coefficients (dimensions, material, shape, etc. of a rod segment), to render the array different bending parameters.

BRIEF DESCRIPTION OF THE DRAWINGS

In order to understand the invention and to see how it may be carried out in practice, some embodiments will now be described, by way of non-limiting examples only, with reference to the accompanying drawings, in which:

Fig. 1 is a representation illustrating a breakwater in accordance with an embodiment of the present invention protecting a dock;

Fig. 2 is a closer representation of the breakwater of Fig. 1, where also some of the submerged elements are viewed;

Fig. 3A is a schematic side view of an anchoring arrangement of a breakwater in accordance with a first embodiment of the present invention, as in Fig. 1;

Fig. 3B is a schematic side view of an anchoring arrangement in accordance with a different embodiment of the present invention;

Figs. 4A-4D are detailed views of different elements used in conjunction with the assembly of the present invention;

Fig. 5 is directed to a deck used in conjunction with a breakwater of the present invention, wherein:

Fig. 5A is a front view of a breakwater fitted with a deck; and

Fig. 5B is a sectioned view taken along line V-V in Fig. 5A;

Fig. 6 illustrates a modification of the invention wherein rod segments comprise different elasticity coefficients;

Fig. 7A illustrates an anchorage constructed of two breakwaters in accordance with the present invention anchored to a land portion;

Fig. 7B illustrates a breakwater in accordance with an embodiment of the present invention serving as a port entry;

Fig. 8 illustrates a breakwater in accordance with the present invention used as a temporary off-shore moor deployed from a ship;

Fig. 9 illustrates an off-shore moor;

Fig. 10 illustrates how a breakwater in accordance with the present invention may be used for defining a confined marine space;

Fig. 11A illustrates a breakwater in accordance with the present invention fitted with improved mooring arrangements; and

Fig. 11B is a side view showing in more detail a mooring arrangement as in Fig.11A.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Fig. **1** is a bird's view of a breakwater in accordance with an embodiment of the present invention generally designated **20** comprising an array of rods **22** fixedly secured as will become apparent hereinafter and retained in the open waters at an arced/bowed configuration by means of bending force applied to respective ends **26** of the array thereby attenuating waves at the area designated **30**, offering reduced sea state wave conditions around the deck **32**.

With further attention directed also to Fig. **2**, the breakwater **20** is seen in more detail and it is noticed that the array **22** comprises a plurality of longitudinal rods **26** parallelly retained at a substantially vertical/upright position, partially submersed in the water.

The rods are typically manufactured by an extrusion process and are made, for example of any combination of materials such as plastic, epoxy, polyester and may be reinforced by various fibers such as Kevlar®, glass or charcoal fibers, etc., as known in the art. The rods are flexible and are normally biased to return to their straight position.

Parallel relationship and the fixed position of the rods with respect to one another is obtained by end pieces **31** (one seen in Fig. **2**) and a plurality of retention members **32** and connecting members **34**, as will be explained hereinafter in more detail with reference to Figs. **4A-4D**.

The breakwater **20** has a bowed shape owing to the force applied thereto in a radial/tandem direction wherein the end piece **31** is linked to a buoy **40** via link **42** and buoy **40** is in turn anchored via cable **44** to a concrete slab **46** lying on

the sea bed. It is appreciated that the link **42** and cable **44** may be made of chains, cables, rods, etc. imparting various degrees of freedom. It is further appreciated that the positioning of the anchor, namely, slab **46** or other suitable anchor (e.g. natural rock, steel anchor, etc.) will result in obtaining different arcs of the breakwater.

The purpose of buoy **40** is to reduce vertical force vector acting in a downwards direction, to thereby stabilize the array **22** at a more-or-less fixed level, whereby a vertical degree of freedom is absorbed through the buoy **40**. It is however appreciated that the end piece **31** may be directly connected to the anchor **46**. It is further appreciated that the length of cable **44** may be changeable upon demand to change the shape of the breakwater, depending on magnitude and direction of waves. It is further appreciated that in case of a serious storm, one or both ends of the breakwater may be detached from the anchor to avoid damage and to better withstand the powerful waves.

Fig. **3A** offers a schematic side view of a modification of a breakwater in accordance with the present invention, similar to that of Fig. **1.** In this embodiment, rods **60** at a lower portion of the array of rods are hollow rods filled with water and upper rods **62** are floating rods, namely rods filled with foamed polyurethane, or the like, to thereby ensure that the array of rods **22** will float. Retaining the array in its upright position as in Fig. **3A** is carried out by a load of weight **66** suspended from the end piece **31**. The weight may be for example a metal payload, etc., and it may also be integrally formed with the lowermost rod **68** or attached thereto, e.g. by link **70**.

The buoy **40** has at its lower end a mass **74** to maintain it at an upright position, as in Fig. **3A**. As in the embodiment of Fig. **2,** the array **22** is secured at its end by an end plate **31** which is linked to buoy **40** by chain **42** and in turn, the buoy is anchored via chain **44** to the anchor slab **46**.

Fig. **3B** illustrates a different arrangement wherein the rods **76** are supported and positioned by a retention member **78** articulated to buoy **80** by two rigid links **82** and supported at an upright position by a load **86** attached at a lower end of

the retention member **78**. The arrangement disclosed in Fig. **3B** may suit for floating the array and may be used as an end-arrangement where suitable anchoring means are provided or as a floating aid positioned in between ends of the array.

Figs. **4A-4D** illustrate sections through different elements used in conjunction with an array of a breakwater in accordance with the present invention.

Fig. **4A** illustrates an end portion of an array of a breakwater in accordance with the present invention wherein the rods **90** are hollow tubes filled with foamed polyurethane and are sealed by end caps **92** (such caps are not necessary for the lower rods which may be opened to allow sea water to enter into the rods). The rods **90** are retained at their fixed position by a retention member **94** in the form of member **78** as illustrated in Figs. **3B** and **4B**, said retention members **78** comprises a plurality of apertures receiving the rods **98** and securing them at a fixed position. The retention member **78** may be slided over the rods or may be clampingly mounted over the array of rods and secured in position by various clamping arrangements (not shown).

Figs. **4C** and **4D** illustrate coaxially extending successive rod segments **102A** and **102B** coupled to one another by a coupling element **104.** Accordingly, an array in accordance with the present invention may consist of a plurality of rod segments of reasonable length to be stored, e.g. in containers or the like, rather than having to store rods of significant length. The coupling element **104** may be attached to the respective ends of the rod segments by snap-engagement, screw coupling as in Fig. **4D**, connecting pins, etc. This arrangement further offers different benefits, e.g. easy replacement of a damaged rod segment, changing the length of the breakwater by introducing rod segments of different lengths, changing the buoyancy parameters by replacing the rod segments by other segments having different buoyancy parameters, replacing rod segments by other such segments having different elasticity coefficients (see Fig. **6**), etc.

Figs. **5A** and **5B** are concerned with mounting a deck **120** in the breakwater, as illustrated for example in Fig. **11A**. The deck **120** may have different purposes, fist it may be suitable for providing accessibility along the breakwater such as in

the example of Fig. **11A** whereby individuals may walk along the breakwater **122** and reach a moored boat, etc. The deck **120** may further be suited for transfer of facilities from the land to boats mooring along a dock, e.g. electricity, fresh water supply, sewage suction, communication cables, etc.

The deck **120** comprises a plurality of T-like deck elements **126** each comprising a substantially flat surface **128** extending above an uppermost rod **130** and a rod engaging portion **134** mounted on several consecutive rods, e.g. by sliding the elements **126** over the rods **130** as in the illustrated example, or by clamping or otherwise attaching thereto (not shown). Typically the deck elements **126** are made of lightweight material, e.g. injection molded plastic and may be filled with foamed material to increase the overall buoyancy of the water break. It is advantageous that a top surface **129** of the deck elements **126** be fitted with an anti-slip arrangement e.g. a roughened surface, a coating of anti-slip material etc.

The rod engagement portion **134** comprises several apertures **138** through which different cables and supply lines may extend, as mentioned hereinabove.

It is further appreciated that the deck elements may be of different size and may be, in accordance with an embodiment of the invention (not shown) be integral with an upper rod of the breakwater.

Fig. **6** is a schematic illustration of a breakwater in accordance with an embodiment of the present invention generally designated **144** comprising a central portion **146** consisting of three rod segments **148** and extending between two end portions **152** in turn consisting of three rod segments **154.** In accordance with this particular embodiment the rod segments **148** of the central portion **146** have a lower elasticity coefficient than rod segments **154** of the end portions **152,** whereby upon applying bending force by articulating ends **160** to anchors **162** the breakwater **144** elastically deforms in a non-homogenous fashion such that the central portion **146** deforms less than the end portions **152.** This arrangement is suitable for obtaining breakwaters of different shapes and spans.

Fig. **7A** illustrates an anchorage **170** along a land portion **172,** said anchorage comprising two breakwaters **174** and **176,** each having a first end **174A** and **176A** respectively, anchored to the land portion and an opposite end **174B** and **176B**, respectively, anchored to the sea bed via buoys **174C** and **176C**, respectively, as explained hereinbefore.

It is apparent from the embodiment of Fig. **7A** that each of the breakwaters **174** and **176** is arced in a different fashion whereby the entrance to the anchorage has an opening at **180** facing a desired direction away from the waves and having a size suitable to facilitate easy maneuvering of boats intended to moor in that anchorage.

It is further appreciated that an anchorage in accordance with such an embodiment is easily assembled and disassembled, requiring only little labor and being inexpensive.

In the embodiment of Fig. **7B** there is illustrated an anchorage **186** of permanent nature comprising two molded concrete breakwaters **188,** or otherwise formed solid breakwaters, defining between them an entrance **190** into the anchorage. The entrance **190** comprises however a secondary breakwater **194** of the type disclosed in accordance with the present invention wherein a first end thereof **196** is pivotally anchored at an end of the fixed breakwater **188** with a second end thereof **198** connected to a winch spool **202** via cable **204.**

The arrangement is such that the entrance into the anchorage **186** is protected by the breakwater **194** to thereby attenuate waves and protect boats moored within the anchorage **186.** However, in accordance with the particular embodiment of Fig. **7B**, the span and direction of the breakwater **194** may be altered, depending on direction and magnitude of the wind, by tensioning or loosening the cable **204.**

In accordance with a particular embodiment, the arrangement may be such that the breakwater **194** may be closed, partially opened or widely opened, at will by, pivoting the breakwater **194** about its pivot end **196,** where it may displace between different positions.

Fig. **8** illustrates an off-shore moor **214** wherein a breakwater **216** in accordance with the present invention is constructed and assembled as previously disclosed wherein its respective ends **218** are tensioned towards one another via cables **220** secured to winches **224** at the bow of a cargo ship **228.**

This arrangement has several particular advantages. For example, the breakwater **216** may be stored aboard the ship **228** and may be erected at any desired position within a short period of time. Second, the position of the ship may continuously change, depending on the direction of wind (in the present example represented by arrow **230)** whereby the breakwater **216** changes its position to maintain a concave position facing the wind.

This arrangement offers attenuating of waves at the surroundings of the ship **228,** to facilitate unloading cargo from the ship to a barge **230.** Such an arrangement may also be used to attenuate waves at the vicinity of ships carrying out different works at open waters, e.g. maintenance of underwater oil pipes, communication lines, etc.

In Fig. **9** there is illustrated an off-shore moor **240,** typically of the kind provided at shallow waters wherein a breakwater **242** is provided, of the type disclosed hereinbefore, with its respective ends **244** tensioned towards one another by cables **246** via buoys **248,** to thereby reduce vertical amplitude, as explained hereinbefore. In the present example there are provided two cables **246** which have the additional purpose of mooring thereto the boats **252** and accordingly, suitable fenders **254** are provided on the cables **246.**

Turning now to Fig. **10** there is illustrated a circular anchorage **258** with an opening **260** leaving entrance into the confined space, where the respective ends **262** and **264** are anchored to a common slab anchor **266.** The arrangement disclosed in Fig. **10** may be used as an anchorage, as a confined swimming zone, as a protecting arrangement for attenuating waves while carrying out different marine works etc.

In Figs. **11A** and **11B** there is illustrated a breakwater **122** fitted with a deck **120** as disclosed hereinbefore with reference to Figs. **5A** and **5B** and where several

mooring rods **272** are provided. The rods **272** are pivotally secured at a first end **276** to a securing member **279** (similar to end plate member **31** as in Fig. **3A**) and are tiltable between a first, substantially upright position (see rods **272A**) and an operative position (rods **272B**) extending substantially horizontally wherein a light boat **278** is moored to the breakwater **122** whereby its stern **280** is anchored to securing members **279** of the breakwater **122** (by rope **281**), and its bow **284** is anchored to ends **286** of the rods **272B** (via rope **288**). This position provides improved support of the boat **278,** also at more rough waters.

Whilst some embodiments have been described and illustrated with reference to some drawings, the artisan will appreciate that many variations are possible which do not depart from the general scope of the invention, *mutatis, mutandis*.